

# **THE STRATEGY FOR THE SECOND PHASE OF AEROBRAKING MARS GLOBAL SURVEYOR**

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## **ABSTRACT**

On February 19, 1999, the Mars Global Surveyor (MGS) spacecraft was able to propulsively establish its mapping orbit. This event followed the completion of the second phase of aerobraking for the MGS spacecraft on February 4, 1999. For the first time, a spacecraft at Mars had successfully employed aerobraking methods in order to reach its desired pre-launch mapping orbit. This was accomplished despite a damaged spacecraft solar array.

The MGS spacecraft was launched on November 7, 1996, and after a ten month interplanetary transit was inserted into a highly elliptical capture orbit at Mars on September 12, 1997. Unlike other interplanetary missions, the MGS spacecraft was launched with a planned mission delta-V ( $\Delta V$ ) deficit of nearly 1250 m/s. To overcome this  $\Delta V$  deficit, aerobraking techniques were employed. However, damage discovered to one of the spacecraft's two solar arrays after launch forced major revisions to the original aerobraking planning of the MGS mission. In order to avoid a complete structural failure of the array, peak dynamic pressure levels for the spacecraft were established at a major spacecraft health review in November 1997. These peak dynamic pressure levels were roughly one-third of the original mission design values. Incorporating the new dynamic pressure limitations into mission replanning efforts resulted in an 'extended' orbit insertion phase for the mission. This 'extended' orbit insertion phase was characterized by two distinct periods of aerobraking separated by an aerobraking hiatus that would last for several months in an intermediate orbit called the "Science Phasing Orbit" (SPO). Figure 1 shows the Revised MGS Mission Timeline. This paper describes and focuses on the strategy for the second phase of aerobraking for the MGS mission called "Aerobraking Phase 2." This description will include the baseline aerobraking flight profile, the trajectory control methodology, as well as the key trajectory metrics that were monitored in order to successfully 'guide' the spacecraft to its desired mapping orbit. Additionally, the actual aerobraking progress is contrasted to the planned aerobraking flight profile. (A separate paper will describe the navigation aspects of MGS aerobraking in detail.)

Key to the success of the MGS mission is the delivery of the spacecraft to its final mapping orbit and the synergy the instrument complement provides to its scientific investigators when science data is returned from that orbit. The MGS mapping orbit is characterized as a low altitude, near-circular, near-polar orbit that is Sun-synchronous with the descending equatorial crossing at 2:00 AM local mean solar time (LMST). This provides for science data collection opportunities along the ascending (dayside) pass of the

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orbit; in other words, the ascending node has a 2:00 PM LMST orientation. The achievement of this mapping orbit with its proper nodal orientation of 2:00 AM LMST (at its descending node) was the principal consideration in the development of the 'extended' orbit insertion phase. Other mapping orbits were considered post-launch after the damage to the solar array was detected but were discounted for various reasons. To achieve the proper nodal phasing of the 2:00 AM LMST Sun-synchronous mapping orbit, the orbit period reduction rate associated with the second phase of aerobraking must closely adhere to the planned aerobraking reference profile.

The aerobraking flight profile for the MGS spacecraft is divided into three distinct sub-phases: a walk-in phase, a main phase, and a walk-out phase. Aerobraking Phase 2 was initiated from the SPO orbit with an initial orbit period of 11.6 hours and a descending node orientation of 5:25 AM LMST on September 23, 1998 -- a nine day delay from the intended Aerobraking Phase 2 start date. Spacecraft telecommunications anomalies and spacecraft sequencing problems triggered the initial delay. Aerobraking main phase was established on September 25, 1998 after a series of three aerobraking walk-in maneuvers were performed. The aerobraking main phase was characterized by steady-state aerobraking conditions as the spacecraft was guided to dynamic pressure limits. To overcome the initial aerobraking delay, the spacecraft was flown at dynamic pressure levels higher than the planned profile for the first two months of main phase. Once the deficit in the orbit period reduction plan was recovered, dynamic pressure levels were re-set to values that achieved the desired orbit period reduction rate commensurate with the proper LMST progression.

Main phase continued until the spacecraft reached its 2-day orbit lifetime point at which time the aerobraking walk-out phase began. The 2-day orbit lifetime is defined as the time necessary for the apoapsis altitude of the orbit to decay to an altitude of 300 km. This is a programmatic constraint aimed at preventing mission failure in the event control of the spacecraft is lost during the final few days of aerobraking, i.e. flight controllers have 48 hours to recover the spacecraft before impact. On January 29, 1999, the aerobraking walk-out phase began and the maintenance of a 2-day orbit lifetime went into effect. Figure 2 shows the actual apoapsis altitude decay history and the location of four aerobraking trim maneuvers that were performed in order to maintain the lifetime requirement during this final critical phase of aerobraking. Aerobraking was terminated on February 4, 1999, with a propulsive (main engine) maneuver when the apoapsis altitude of the orbit had decayed to a value of 450 km and the descending node had reached a 2:04 AM LMST orientation. The aerobraking termination maneuver raised the periapsis of the orbit to an altitude of 377 km and left the spacecraft in an intermediate "transition" orbit as final preparations were made to propulsively establish the MGS mapping orbit.

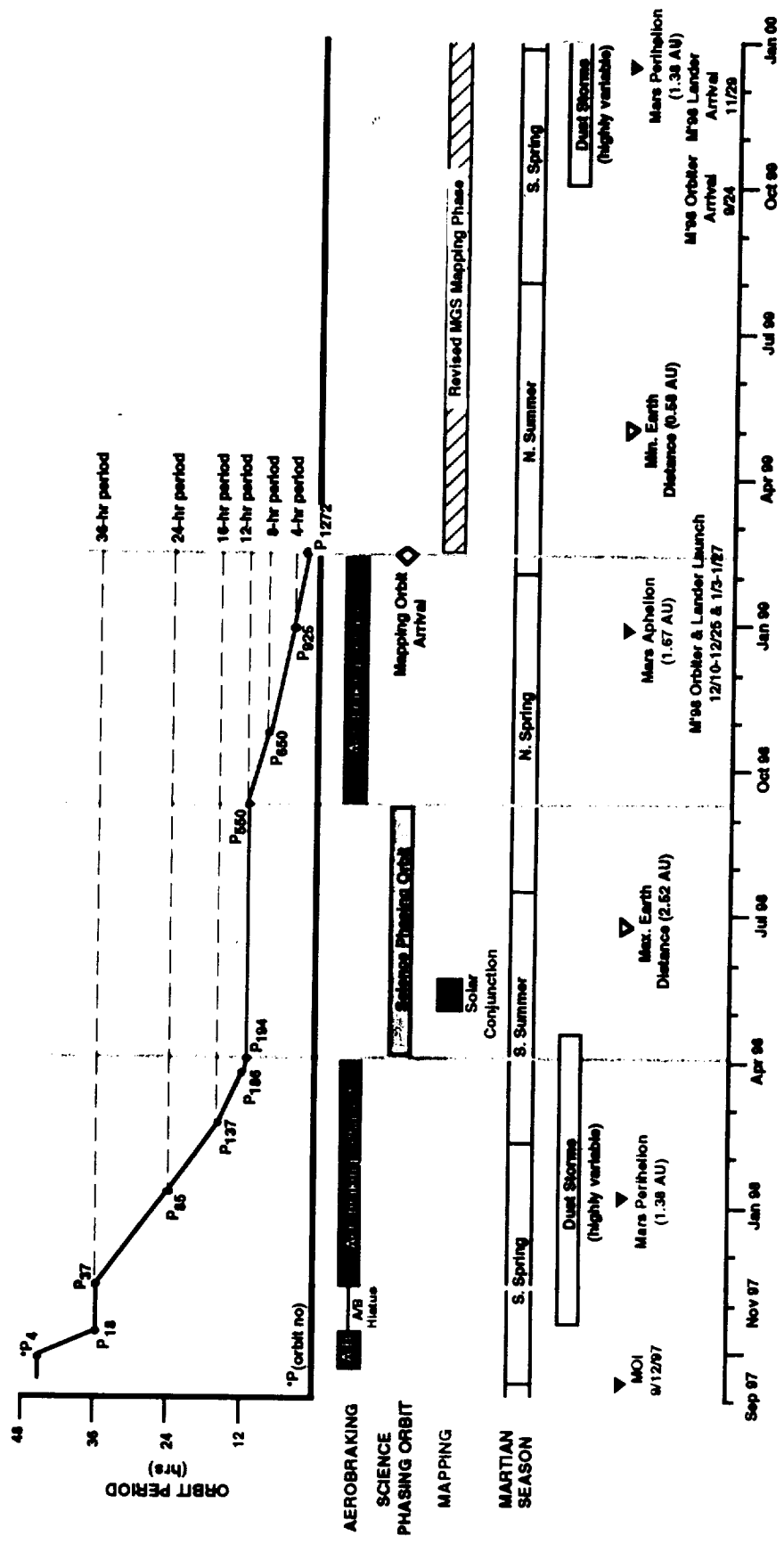


Figure 1 Revised MGS Mission Timeline

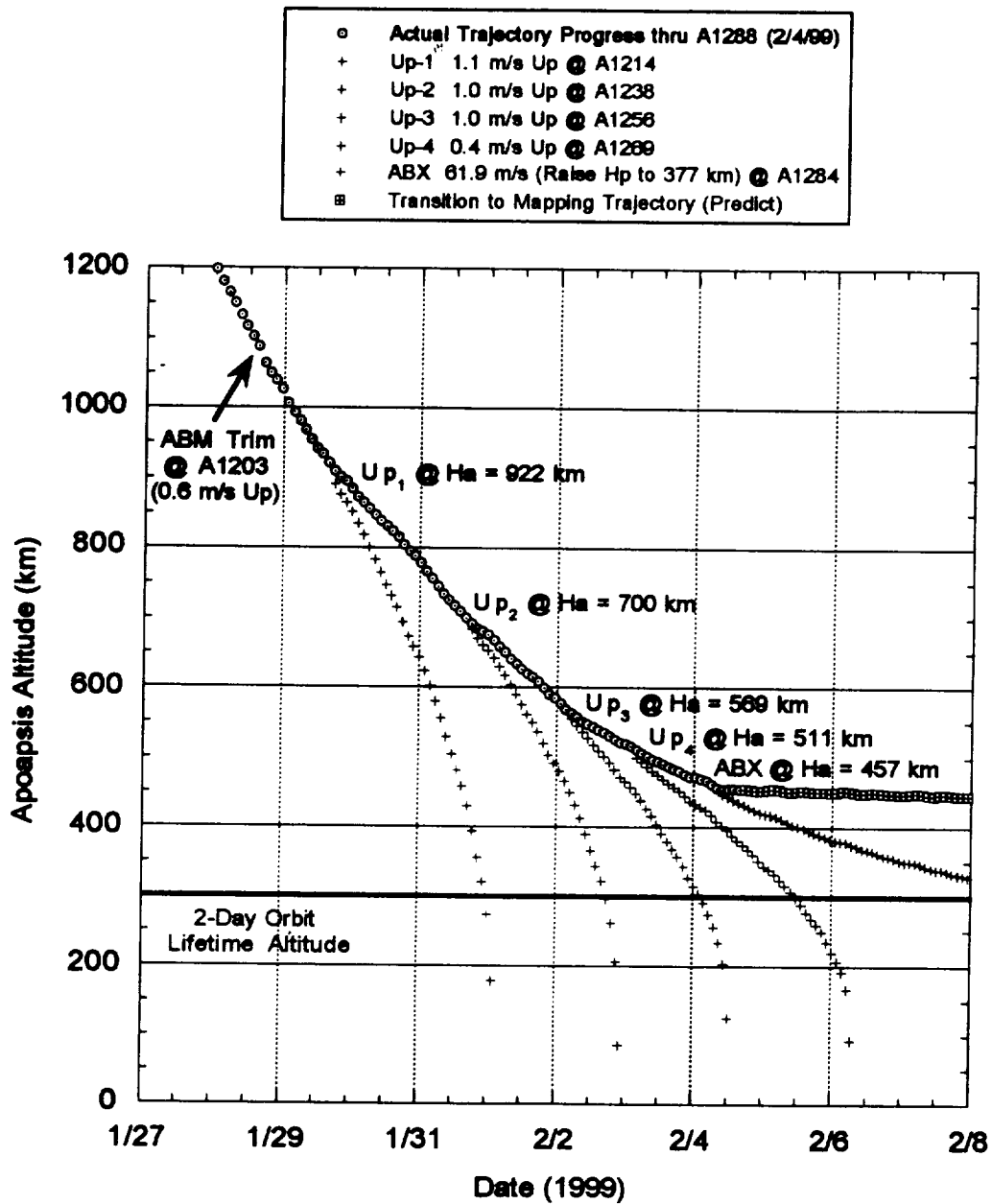


Figure 2 Aerobraking Walk-out Phase